Technology Transfer at Internet Speed

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Abstract –You are the factory manager with two processes running, a third scheduled to ramp down and a fourth scheduled to startup. Then the new loadings forecast comes out and you discover that the process your factory was going to ramp down is ramping up and the new process startup has been pulled in. Is your factory flexible enough to commit to the new loadings forecast and still meet the startup schedule? There is only one way to find out, you go to the Internet and consult the Route and Tool Readiness (RTR) System.

The Route and Tool Readiness system is a spreadsheet-based system accessible from the Intel Intranet, which links information from several different sources to give an integrated view of a startup project. These include tool schedules, route information, throughput time data and engineering contact names.

As the time between process development and process transfer into manufacturing continues to decrease, the RTR system becomes more critical. It enables factory management to successfully deal with last-minute technology changes during transfer, as well as sudden shifts in market demand between multiple technologies. At the same time, it makes technology transfer projects more productive, accurate, and faster.

Index Terms –Startup, ramp, Technology Transfer.

INTRODUCTION

This paper describes the Route and Tool Readiness (RTR) system, a data management tool, which Intel has developed to successfully manage technology transfer information and startups. This tool was used to manage the first 8" Flash startup at Intel's Fab 11 in New Mexico, which set a new Intel record for ramp speed (program start to 3000 WSPW in 11 weeks). In addition, as the transferring factory, Fab 11 was able to utilize the Route and Tool Readiness system to efficiently transfer a new technology to Fab 15 in Oregon. The Route and Tool Readiness system is now the Best Known Method (BKM) for Intel startups throughout the company. The RTR system saves over 1700 work hours per startup by eliminating duplicate work, enabling schedule consolidation, improving information accuracy and by automating various update functions. It also enables factory management to successfully deal with last minute technology changes, as well as sudden shifts in product demanded between multiple technologies and an ever changing market.

SYSTEM OVERVIEW

The Route and Tool Readiness system is a spreadsheet-based system accessible from the Intel Intranet, which links information from several different sources to give an integrated view of a startup project (Fig 1). These include tool schedules, route information, throughput time data, engineering contact names and qualification gate locations. A qualification gate location is a location in the line where production material is held until specified qualification data is approved.

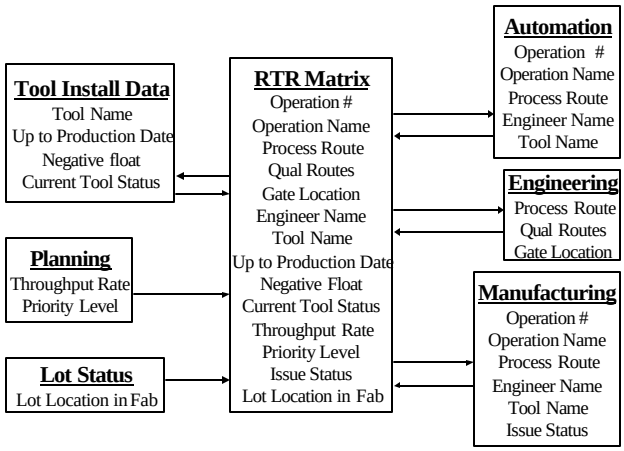

Fig 1. Technology Transfer Data Flow With RTR System

The Route and Tool Readiness system performs the following functions. First, it cross checks the transfer data from multiple databases to ensure that it is consistent. Second, it optimizes the startup schedule based on current business conditions. Third, it identifies and prioritizes key issues in the startup schedule. Fourth, it highlights tool ownership by engineer for every process step. This ensures that tools are ready for production before process qualification begins. Finally, it generates a schedule to manage Qualification (Qual) and First Full Loop (FFL) lot movement and off-hours engineering coverage.

Another key component of the Route and Tool Readiness system is the flexibility it provides during the process transfer. The component structure of the Route and Tool Readiness system allows the receiving Fab to control which portions of the system they actually require for an efficient process transfer. This means that a Fab can tailor the Route and Tool Readiness system to provide data management tools specific to their organization. An unintended benefit that results from this "tailoring" is that the Route and Tool Readiness system is continuously refined and updated as each process transfer

occurs. This enables the Route and Tool Readiness system to meet current as well as future process transfer needs.

FEATURES AND BENEFITS

The Filter Function

The Route and Tool Readiness System filters all transfer information from the transferring factory and within the startup factory to ensure that there is only one set of transfer data. The two key things that are filtered are the routes (Process and Qualification) and the startup tool set. Automating this function has saved Intel 244 work hours per startup.

Before the Route and Tool Readiness system was implemented different departments within the same factory worked from different versions of the process route to be transferred. This caused tools to be worked on that were not needed and prevented work from being done on tools that were needed. By providing a single source for route information that is regularly verified and updated it ensures that all departments are working on the same route, minimizing duplicate efforts.

The filter function also identifies the startup tool set and ensures that there is one and only one tool for each process step. This eliminates scope creep. The startup tool set is the minimum group of tools that is needed to process the Qual lots and the First Full Loop.

Prior to implementing the Route and Tool Readiness system it was very difficult to determine which tools were the critical tools to work on. Often engineers would attempt to simultaneously qualify multiple tools for a single operation in an effort to get the best tool in the factory for startup and to create redundancy. To accomplish today's aggressive process transfer rates program scope must be controlled such that only the work critical to startup is focused on.

The other benefit of defining a single tool set is that Walk The Lot (WTL) can be performed on the same tool that will be used for Qual and First Full Loop processing. Walk The Lot is the exercise of running test silicon on the process tools after they are qualified to ensure that all processing issues are resolved before Qual silicon arrives. By ensuring that WTL is performed on each tool the chances of successful processing the first time a tool sees Qual silicon are greatly increased.

The Scheduling Function

After the data is filtered and input into the matrix the startup schedule can be analyzed and optimized based on current business conditions and tool install/qual constraints. This serves two purposes. First, it gives management a tool to determine the startup schedule. By adjusting the First Full Loop (FFL), Qual lot start dates and throughput time (TPT) any startup schedule can be optimized based on current business conditions and/or tool constraints. Second, it allows the user to quickly analyze the schedule using different 'What If' scenarios. Automating this function has saved Intel 42 work hours per startup.

The two key driving forces of the startup schedule are how many die are needed and how fast. Reviewing the startup schedule with respect to the current Long Range Plan (LRP) optimizes the startup timing based on when product is needed in the marketplace.

Reviewing the startup schedule with respect to tool availability has a twofold result. First, it answers the question 'When would I be able to sell my product if the tool install negative float doesn't change?'. Second, it answers the question 'What tools should I focus on to have the greatest impact to the startup schedule?'.

The Prioritizing Function

The Prioritizing Function is part of the weekly comparison between the tool install schedule and the startup schedule. Tool need date does not correspond linearly to process flow throughput time because the Qual routes break the process flow into segments which can be run in parallel or serial. To complicate matters, not all process steps are part of a Qual route so the first silicon that those steps see is the First Full Loop lot. To comprehend these effects the Prioritizing Function was created and automated. Automating this function has saved Intel 104 work hours per startup.

The earliest date that each tool is needed for silicon (either Qual or First Full Loop) is extracted from the Route and Tool Readiness matrix and compared to the expected up to production (UTP) date in the tool install schedule. If the tool UTP date is later than the date it is needed for first silicon the tool is late. By evaluating the late tool group based on negative float to first silicon need date the prioritization is optimized.

The Engineering Link Function

The Engineering Link Function serves two purposes. First, it allows engineering and automation groups a shared space to complete the Bulk Workstream Change Request (BWCR). Workstream is the database, which contains the tool and process information that runs the factory. Second, it is a key communication tool between engineering and manufacturing. Automating this function has saved engineering 156 hours on initial entity setup. It has saved automation; 120 hours on operation and route setup by allowing automatic loading of database, 160 hours on entity setup, 208 hours to follow up on discrepancies eliminated, 52 hours synchronizing and validating the process route. .Automating this function has saved Intel 696 work hours per startup.

The BWCR is a working document that defines the Workstream setup for each tool. It is linked to the Route and Tool Readiness system to ensure that the route is current and to define the dates that the Workstream setups must be implemented. The BWCR is also used to identify and resolve equipment setup conflicts early so that they can be resolved well in advance of the equipment setup transfer.

The same update system that engineering uses to update the BWCR is used to update the Route and Tool Readiness matrix with the on call status of individual engineers. This is how manufacturing determines which engineers are needed on site for Qual and First Full Loop lot processing.

The Lot Tracking Function

The Lot Tracking Function is used as a planning and tracking tool for manufacturing and engineering to manage Qual and First Full Loop lot movement and off hours coverage. The individual engineers use the model as a best guess estimate of when a lot will arrive at their operations. The engineering groups look at the next 24 hours and make coverage plans, which are communicated to manufacturing by the Route and Tool Readiness area engineers who own updating the Route and Tool Readiness system. Manufacturing uses the Engineering View to manage on-site engineering coverage and uses the Lot Tracking Function as a way to prioritize lots based on the buffer between the First Full Loop lot arrival date and the expected date the Qual gate will open. A qualification gate location is a location in the line where production material is held until specified qualification data is approved. Automating this function has saved Intel 672 work hours per startup.

From the Route and Tool Readiness matrix the Qual and First Full Loop lot numbers are input to a DCL (digital command language) based program that extracts the last arrival time/date stamps from the Factory Resource Status Board (FRSB) data file. The time/date stamps are entered into the appropriate cells on the Lot Tracker View. Those cells are automatically highlighted to indicate the last move out that was completed for each lot. The frequency of update is defined by submitting the Job Scheduling System. The current timing is once every 15 minutes, which is how often the FRSB data file is updated.

SYSTEM SET UP AND PHASES

The Route and Tool Readiness System is a series of Excel based spreadsheets that use Excel macros to highlight changes and identify discrepancies. All spreadsheets reside on a WEB server and are accessible via the Intel Intranet. To facilitate the analysis of the data there is a series of meetings that range from weekly to monthly depending on what team you are on and what phase of startup you are in.

There are three key teams within the Route and Tool Readiness system. The Matrix Managers consist of the tool install schedule owner, a tool install team representative, an integration route owner, an automation route owner, the Rout and Tool Readiness Matrix Manger, a manufacturing representative and a planning representative. The Bulk Workstream Change Request team (BWCR) consists of automation and engineering. The Walk The Lot Run Card team consists of automation, manufacturing and engineering.

There are three phases to the RTR System. Phase I is 'Tool Install Solidification', Phase II is 'Startup Optimization' and Phase III is 'Startup'. Each phase currently lasts 2-4 months and overlap such that total process is 6-8 months long.

Phase I: Tool Install Solidification

Phase I, 'Tool Install Solidification' requires that the process and Qual routes have been synergized. This effort is led and owned by the Matrix Managers and uses the Filter, Scheduling and Prioritizing Functions.

To use the Filter Function, the route is downloaded into the Route and Tool Readiness matrix from the same database used by the Tool Install Schedule. Automation then electronically compares the route from the transferring factory to the route in the RTR matrix. Using a TeamStation automation, the integration route owner and the Matrix Manager review the discrepancies and update the RTR matrix appropriately. The first route synergization meeting may take 1-2 hours. Subsequent meetings occur monthly and take 20-45 minutes depending on the quantity of changes. The last 4-6 weeks before startup route reviews are held weekly and last 10-20 minutes.

Once the routes have been synergized the planning group provides the throughput time for each process step and then the Scheduling Function is used to define the Ideal Schedule. Working backward from the Ship Release date the Route and Toll Readiness Matrix Managers determine the latest that each Qual lot could start without gating the First Full Loop. It is assumed that the Qual throughput time is slow and the First Full Loop Lot throughput time is fast to simulate the worst-case scenario.

While the Ideal Schedule is being defined the tool install scheduler works with the tool install team representative and the Route and Tool Readiness Matrix Manager to define a tool name for each operation number in the process flow. This is a manual process, as it is done no place else.

After the Ideal Schedule is defined and the tool names are linked the Matrix Managers begin weekly Route and Tool Readiness matrix reviews. The Scheduling Function is used to identify issues and opportunities. At the same time the tool install schedule owner runs a weekly comparison (Filter Function) to verify synchronization between the tool install schedule and the Route and Tool Readiness matrix. The discrepancies are output to an excel spreadsheet and resolved by the tool install team.

In addition to resolving discrepancies between the tool install schedule and Route and Tool Readiness matrix, the date that a process step is first exercised by either Qual or First Full Loop silicon is compared to the date the process tool needed for that operation is available. The difference between these two dates is the negative float to 1st silicon. Key schedule drivers are identified and tool install priorities are communicated to the program management team.

Phase II: Startup Optimization

In addition to the routine reviews started in Phase I, the startup schedule is optimized on an as needed basis during Phase II. The startup schedule can be optimized in several ways. It can be optimized to minimize impact to manufacturing by running the Qual's sequentially; it can be optimized to qualify the process as quickly as possible by running them in parallel or any variation in between. The driving factor to the schedule logic is the ability for Intel to supply the product demanded by the market without impacting any other processes that are running.

The Engineering Link Function owned by the Bulk Workstream Change Request team (BWCR team) is also utilized during Phase II. The BWCR team begins populating the BWCR after the initial startup schedule is optimized. At each schedule optimization the BWCR team re-priorities their implementation sequence accordingly. The BWCR team meets weekly. At first meetings focus on how to use the BWCR, then transition into brief shared learning sessions.

Phase III: Startup

The Startup phase begins with Walk The Lot (WTL) preparation. Included in this phase are the communications for manufacturing and engineering regarding what a process startup is, how to process Qual and First Full Loop lots and coverage expectations. The successful Startup phase ends when all Qual gates are opened before the First Full Loop arrives such that the required amount of First Full Loop material is processed in time to meet market demand.

The WTL Run Card team owns the critical link between WTL and Route and Tool Readiness matrix. Walk The Lot is the final check to verify that each tool is ready to process silicon. Tools that pass Walk The Lot rarely have any processing issues when the first silicon is processed. By correlating the route and tool used for Walk The Lot with the Route and Tool Readiness matrix the success of the startup is increased by ensuring that one tool for each process operation has completed Walk The Lot . The WTL Run Card team meets weekly for 4-6 weeks to update the run card, then disbands.

During the 6-8 weeks before Walk The Lot begins the entire Route and Tool Readiness team spend 1-2 hours a week reviewing and updating the standard WEB based training package. Two weeks prior to the start of Qual lots the training is delivered to process engineering and manufacturing by Route and Tool Readiness team members.

Qual lot processing leading to successful gate opening is the last step of startup. During this time the Route and Tool Readiness team is almost totally inactive. The Matrix Managers who support the Lot Tracker (Matrix Manager and Manufacturing representative) and the Route and Tool Readiness area engineers who own updating engineering on call status are the only active members of the Route and Tool Readiness system. The Lot Tracker is updated using the Lot Tracking Function and is used by; the manufacturing supervisors that own successful lot movement, process engineers to determine schedules, Fab population in general to determine performance to schedule and startup status.

The Matrix Managers support the Lot Tracker by providing 7 day x 24 hour on call coverage for questions. The average is 1-2 per shift the first shift the Tracker is used, then 1-2 per week. The Route and Tool Readiness engineering representatives update the Lot Tracker with engineering on call requirements daily. This is a 5-10 minute task. A startup meeting is held daily starting a few days before the Qual lots start and ending when all gates are open. The chair of this meeting alternates between the Route and Tool Readiness Team Leader and a lead integration resource. The Route and Tool Readiness matrix is posted in a public place to communicate lot location, performance against schedule and gate status.

SUMMARY

The Route and Tool Readiness system links the tools setups and schedule, Process and Qual routes, throughput time data, engineering contact names and Qual gate status. The system ensures that all teams within the startup factory use the same data set. It eliminates duplicate work, helps to prioritize work, serves as a planning tool and acts as a lot management tool.

The Route and Tool Readiness system was developed by Intel to successfully manage technology transfer information and startup. The Route and Tool Readiness system saves Intel over 1700 work hours per startup, not including time saved by eliminating unnecessary and duplicate work (see Table I).

Table I. Work Hours Saved Per Startup

What was automated	Hours saved per startup
Filter Function	244
Scheduling Function	42
Prioritizing Function	104
Engineering Link Function	696
Lot Tracking Function	672
Total	1758

To remain competitive in the current business environment Intel is finding it necessary to take increasingly complex processes from development to sustained manufacturing in less and less time. Technologies being transferred are often still changing as they are being transferred, market demands are constantly shifting and Internet fast decisions are critical to meet these challenges and make our startups better and faster. The Route and Tool Readiness system effectively manages the tremendous amount of information that a process transfer requires. It enables factory management to successfully deal with last-minute technology changes during transfer as well as responding to sudden shifts in market demand between multiple technologies. Utilizing the data management capabilities of the Route and Tool Readiness system allows technology transfer project times to be shortened while maintaining the level of accuracy needed for a successful transfer.